EFFECTS OF REVERSAL IN THE HUMAN EQUILIBRIUM REGULATION SYSTEM

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The postural reactions induced in man by bilateral vibration of the tibial muscles under various conditions were investigated: sitting with feet not in contact with support; sitting in an unstable position on a narrow seat; sitting with feet in contact with different types of support (suspended platform, turntable, etc.); standing with an asymmetrical load applied to the body. It was demonstrated that local vibration of the tibial muscles can induce not only activation of the vibrated muscle or its antagonist (local effects), but excitation of the extensors and flexors of the knee joint (nonlocal effects) or remote muscle groups participating in the realization of various postural synergies. The specific activation of the muscles is determined by a number of factors, among which the most important are the reciprocal position of the members of the body and the interaction of the feet with the support. The reflection of the configuration of the body in the system of internal representation also plays an important role.
Fig. 1. Drawing of the experiment. a) Subject is sitting on a tall chair, feet not in contact with the floor (the position of the vibrator above the Achilles tendon is designated by a circle); b) subject dressed in a special loading suit with nonidentical pulling force; c) subject in an unstable position.

INTRODUCTION

Instances have been described in the course of investigations of the reflex reactions of vertebrates (Sechenov, Sherrington, Beritov) and invertebrates (Uexküll) in which reactions have arisen of the opposite sign in response to the stimulation of one nerve or another, depending upon the initial state of the musculoskeletal system and the nervous system. Such effects have been termed reversal (reflex umkehr, umschaltung, reversal, switching). Magnus subsequently systematized these observations, and on the basis of his own results came to the conclusion that reversal reactions are an essential part of the mechanisms of postural regulation.

A new wave of interest in the revrs has appeared in recent years. Thus, it was demonstrated [9] that the presence of a painful focus leads to changes in phases during locomotion in the intact cat. Phase-dependent revrs which arose in response to stimulation of skin receptors of the anterior surface of the foot have been found in spinal cats [5, 6, 13]. Changes in the reaction of the muscles to stimulation of one and the same cutaneous nerve which are dependent on the phase of the cycle during walking have also been identified in man [4].

There are data on the occurrence in man, under postural maintenance conditions, of reversal reactions [1-4] determined by postural factors (the mutual position of body members, the presence or absence of support, etc.) and by visual monitoring [11]. In all these observations we are dealing with reversals within the limits of the agonist-antagonist pair. However, if the revrs are not simply laboratory phenomena, but operating mechanisms which participate in the maintenance of equilibrium, then there must also exist, in addition to local reversals from the agonist to the antagonist, more complex reactions which involve remote muscles.

The objective of the present study was the identification of the nonlocal reversal effects and an attempt to interpret their role in equilibrium maintenance reactions.

METHODS

The vibrational stimulation of the m. soleus and the m. tibialis anterior was carried out by means of vibrators (direct current motors with cams) attached over the muscle tendons by rubber bands. The amplitude of the vibration was 0.6-0.8 mm, the frequency 60-80 Hz; the duration could vary depending on the type of experiment and the sensitivity of the subject to vibration. The electrical activity of a number of superficial muscles and mechanograms of movements of body members were recorded.

Four series of experiments were performed, differing in the methods used in carrying them out. Therefore each series will be described separately. Twelve subjects participated in the experiments.

In the first series the subject sat in a tall chair so that his feet would not touch the floor (Fig. 1a). The angles of flexion in the knee and pelvic-femoral joints were 90°. The